WHAT IS CLAIMED IS:

1. A computer-implemented method for designing an electromagnetic coil arrangement that generates a uniform magnetic field in a desired region, said electromagnetic coil arrangement having a number of coils and a shape defined by r and z, where r is the radial coordinate of a cylindrical coordinate system having (r, z, φ) coordinates, and z is the axial coordinate of the cylindrical coordinate system; comprising the steps:

(a) computing a solution to Eq. (25) as defined in the accompanying specification for a set of parameters lambda_j under the conditions recited in Eqs. (5), (6), and (8) of the accompanying specification,

(b) using a computer, numerically evaluating Eq. (14) as defined in the accompanying specification using the set of parameters lambda_j computed in step (a) to obtain an ideal current density J(r, z) for the electromagnetic coil arrangement to generate a desired magnetic field intensity,

(c) plotting J as a function of r and z as computed in step (b) to obtain the number of coils and the shape of the electromagnetic coil arrangement to determine its geometry.

2. A computer-implemented method for designing an electromagnetic coil arrangement that generates a uniform magnetic field in a desired region as set forth in claim 1, wherein the desired region is an imaging region of interest for a magnetic resonance imaging system, and step (b) reformulates the set of parameters lambda_j computed in step (a) into the standard form of Eq. (14) to give the ideal current density for a selected coil feasible volume producing in the imaging region a selected magnetic field intensity.

3. A computer-implemented method for designing an electromagnetic coil arrangement that generates a uniform magnetic field in a desired region as set forth in claim 2, further comprising the step:

(d) numerically evaluating Eq. (9) as defined in the accompanying specification using the

result obtained in step (c) to determine the minimum coil volume of the electromagnetic coil arrangement.

4. A computer-implemented method for optimizing the design of an electromagnetic coil arrangement that generates a uniform magnetic field in a desired region, said electromagnetic coil arrangement having a number of coils and a shape defined by r and z, where r is the radial coordinate of a cylindrical coordinate system having (r, z, φ) coordinates, and z is the axial coordinate of the cylindrical coordinate system; comprising the steps:

(a). Select a feasible volume for the coils,

(b). Select a desired current density magnitude for the coils,

(c). Select a desired magnetic field level for the desired region,

(d). Select the number and values of harmonics to be controlled in the desired region,

(e) computing a solution to Eq. (25) as defined in the accompanying specification for a set of parameters lambda_j,

(f) reformulating the solution to Eq. (25) to the standard form of Eq. (14) as defined in the accompanying specification using the set of parameters lambda_j computed in step (f) to obtain an ideal current density J(r, z) for the electromagnetic coil arrangement which generates an approximation of the desired magnetic field level,

(g) plotting J as a function of r and z as computed in step (g) to obtain the number of coils and the shape of the electromagnetic coil arrangement to determine its geometry.

5. A computer-implemented method for optimizing the design of electromagnetic coil arrangements that generate uniform magnetic fields in a region of interest for a magnetic resonance imaging system as set forth in claim 4, wherein computing a solution to Equation (25) in step (f) for a set of parameters lambda_j involves the following constants and variables wherein:

M = number of harmonics controlled, including the fundamental and the fringe field harmonics;

lambda_j = a set of M+1 parameters that determine the ideal current density configuration for the coil arrangement as set forth in Equation (14);

J_0 = the desired current density magnitude;

c_m = set of M desired values for the harmonics;

c_1 = is the field level at the center of the region of interest; for harmonic cancellation, the c_m are zero for m > 1;

r = the radial coordinate of a cylindrical coordinate system having (r, z, φ) coordinates;

z = axial coordinate of the cylindrical coordinate system;

D = the region of an rz plane corresponding to the feasible volume of the region of interest;

Theta() = the standard mathematical step function defined by Equation (15);

g_j() = constraint functions that depend on the choice of the type of harmonics to be cancelled (e.g., spherical, ellipsoidal, etc.). For spherical harmonics, they are given by Equation. (21);

P_j() = the standard mathematical Legendre polynomials (in Equation (21));

mu_0 = the magnetic permeability of free space (in Equation (21)).

6. A computer-implemented method for optimizing the design of electromagnetic coil arrangements that generate uniform magnetic fields in a region of interest for a magnetic resonance imaging system as set forth in claim 4, wherein the electromagnetic coil to be designed comprises plural turns each having a given current that is the same for all the turns, the turns are connected in series with a uniform wire size and turn density, the coils are restricted to lie within the feasible volume, the magnetic field in the imaging region depends linearly on the current density, and the characteristics of the field including its magnitude and uniformity may be fixed by controlling a set of harmonics.

7. A computer-implemented method for optimizing the design of an electromagnetic coil arrangement that generates a uniform magnetic field in a desired region, said electromagnetic coil arrangement having a number of coils and a shape defined by r and z, where r is the radial coordinate of a cylindrical coordinate system having (r, z, φ) coordinates, and z is the axial

coordinate of the cylindrical coordinate system; comprising the steps:

I) Select a feasible volume for the coils;

II) Select a desired current density magnitude for the coils;

111) Select a desired magnetic field level for the imaging region;

IV) Select the harmonics to be canceled for the imaging region or select target points about the imaging region;

V) If reduction in a fringe field is desired, select the harmonics to be canceled for the fringe field region or select target points in the fringe field region;

VI) If target points are used, apply linear programming with the constraints of Eqs. (5), (6), and (12) as set forth in the accompanying specification and compute a coarse-grained solution for the current density, and from this solution determine values for the harmonic coefficients of the field;

VII) Compute the solution to the master Eq. (25) as set forth in the accompanying specification for a set of parameters lambda_j;

VIII) Substitute the solution of step VII for the lambda_j into the standard form as per Eq. (14) as set forth in the accompanying specification to give the ideal current density;

IX) If rectangular coils are desired, partition the domain D into rectangular subregions, and replace the functions g_j (r, z) with g (r, z) as defined by Eq. (37) as set forth in the accompanying specification, and repeat steps VII and VIII;

X) If power minimization is desired, repeat steps I-VIII for a range of current density magnitudes, and compute power consumption for each case, and chose the one with the minimum power for the corresponding current density;

XI) If rectangular coils are desired, repeat step IX to obtain rectangular coils.

8. A computer-implemented method for optimizing the design of electromagnetic coil arrangements that generate uniform magnetic fields in a region of interest for a magnetic resonance imaging system as set forth in claim 7, wherein in step VIII, use a number of target points less than one thousand.

9. A computer-implemented method for optimizing the design of electromagnetic coil arrangements that generate uniform magnetic fields in a region of interest for a magnetic resonance imaging system as set forth in claim 7, if additional computation is desired to increase the accuracy of the coil arrangement, use a number of target points greater than several thousand.

10. A computer-implemented method for optimizing the design of electromagnetic coil arrangements that generate uniform magnetic fields in a region of interest for a magnetic resonance imaging system as set forth in claim 7, wherein the electromagnetic coil is a superconductive coil whose volume is minimized.

11. A computer-implemented method for optimizing the design of electromagnetic coil arrangements that generate uniform magnetic fields in a region of interest for a magnetic resonance imaging system as set forth in claim 7, wherein the electromagnetic coil is a resisitive coil whose power consumption is minimized.

12. A superconductive coil arrangement for use in MRI designed by the method of claim 4.

13. A resisitive coil arrangement for use in MRI designed by the method of claim 7.

14. A rectangular coil arrangement for use in MRI designed by the method of claim 7.